Die Face Engineering based Springback Compensation Strategy and Implementation

Arthur Tang, Wing Lee, Jeanne He, Jinbo Xu, Kesu Liu and Chin Chun Chen
Engineering Technology Associates, Inc.
Troy, Michigan
U.S.A

Abstract. Springback or shape change has been one of the major challenges in sheet metal fabrication, particularly with increase application of high strength steel (HSS) and aluminum alloys in automotive stamping. Springback, an elastic material recovery after the unloading of stamping tools, causes variations and inconsistencies of final part dimensions. Minor or mild springback usually can be corrected in the re-strike process. Excessive springback must be corrected so the part will be produced within the given design tolerance and dimension. The commonly used Spring Forward approaches and shape compensations such as over-crown and over-bending are proven effective to alleviate excessive springback. To enhance these approaches, a new strategy of Die Face Engineering (DFE) based processing is proposed to quickly and easily to achieve the maximum allowable compensation using the under cut (or die lock) as the primary criteria. The implementation of the die face compensation through iterative FEA calculation, automatic surface mapping, projection and manual morphing are crucial to meet production environment requirements in terms of generating NC quality CAD surfaces of the compensated or morphed die face. In this paper, the strategy of the die face compensation with the consideration of the under cut criteria is presented. The implementation of various processes to enable user to perform the die face compensation task in a production environment is also discussed. Finally, two examples are shown to demonstrate the implementation of the proposed springback compensation scheme based on the combined CAE/CAD methodology.

INTRODUCTION

In recent years, the advances in automotive manufacturing have resulted in increasingly application of lighter gauge high strength steel (HSS) and aluminum alloy sheets in automotive stampings, as opposed to the conventional mild steel grades. The application of such advanced materials has posed challenging issues during sheet metal fabrication. One of the greatest challenges is springback. Springback or shape change is an elastic material recovery after the unloading of stamping tools and removal of stamped parts from stamping tools. It causes distortions and dimensional inconsistencies of stamped part.

For over two decades, numerous researchers have studied springback phenomena. For examples, Ayres [1], Davies [2], Hayashi [3], and Shi [4] conducted experiments to study springback behavior. The popularity of FEM simulation of the sheet metal stamping process since 1990s has encouraged many researchers to attempt springback analysis by different numerical techniques [5-11]. However, the approach yields limited success due to the lack of development in both numerical techniques and experimental understanding. To further understand prediction of springback using FEM simulation, many research groups such as Liu et. al. [12-14], Onipede et. al. [15], Zhu and Maker [16-17] have carried out more investigations on FEA of springback analysis.

Springback causes undesirable final part quality and creates difficulties in downstream assembly processes. In addition, it slows down new product launches, increases changeover time and the associated cost. In stamping production, minor or mild springback is usually corrected with the re-strike processes. As for excessive springback, correction must be made so the stamped part will be produced within the given design tolerance and dimension. The commonly used Spring Forward/Backward and shape compensations such as over/under-crown and over/under-bending have been proven effective to alleviate excessive springback.

In this paper, the strategy of the die face compensation with the consideration of the under cut criteria is presented.
Additionally, the implementation of various processes to enable user to perform the die face compensation task in a production environment are discussed. These processes include automatic surface mapping, projection and manual morphing. The die face compensation of U-Channel and Rail are illustrated to demonstrate the implementation of the proposed springback compensation scheme based on the combined CAE/CAD methodology.

**DIE FACE ENGINEERING**

The eta/DYNAFORM stamping simulation software is packaged with both the explicit and implicit finite element analysis (FEA) solvers LS-DYNA [21,22] which produce springback results of a particular deformed blank on a die face. The Die Face Engineering (DFE) is a toolbox provided in eta/DYNAFORM for incremental stamping FEA users to design and engineer the draw die, including binder and addendum from the part geometry. The DFE module was developed to enable the users to quickly derive a suite of binder and addendum surfaces as a baseline tooling design for further formability feasibility study. As a result, it reduces iteration time for tooling design and development cycles. At the end, the module helps to reduce the associated cost.

The architecture of DFE in eta/DYNAFORM Version 5.2 [23] provides one-code, one-environment pre-processor for stamping simulation. It allows the user to easily design and re-engineer the die tooling using the numerous automated functions available in the software. The DFE contains both semi- and fully-automated features such as element fillet, reverse trimming, outer smooth, binder generator, addendum generator, morphing, tipping, surface mapping, draw bar, sausage and so on. Some of these features related to the topic are briefly discussed in the following section.

**Morphing**

Line, surface and mesh morphing are all offered in the DFE module for stamping engineers to easily manipulate Punch Opening Plus (POP) lines, reverse trimming functions, addendum and binder surface design.

**Tipping**

The tipping function places the part into die position from the design position. In DFE, tipping process can be carried out manually and/or automatically. After tipping process, the undercut can be identified by plotting the tipping contour. In addition, the draw depth is estimated, per the reference of the “Point of the First contact”.

**Surface Mapping**

This function enable user to map the original CAD Die Surfaces to the morphed mesh and/or springback compensated mesh. As shown in Figure 1, the Surface Mapping function in DFE provides three types of projection methods. The Adaptive Normal, Mesh Normal and Surface Normal enable surface projection along the adaptive normal orientation, mesh normal and surface normal, respectively.

![Surface Mapping](image.png)

**FIGURE 1.** An illustration of Surface Mapping dialog in eta/DYNAFORM DFE module.
DIE FACE ENGINEERING BASED STRATEGY TO COMPENSATE SPRINGBACK

The Springback FEA results, include the forces, stress, strain, displacement and displacement vector are the criteria for determining the amount of springback compensation needed on the die surface using a method generally referenced as Spring Forward [18-20]. To enhance the approach, a new strategy of Die Face Engineering (DFE) based springback compensation methodology is proposed to quickly and easily to achieve the maximum allowable compensation using the under cut (or die lock) as the primary criteria. Furthermore, the strategy mainly focuses on FEM mesh.

The User Graphic Interface (GUI) of DFE based springback compensation is shown in Figure 2. The GUI enables implementation of die face compensation using the springback results from original tooling. It consists of four major areas: (a) Select Nodes (b) Undercut Option, (c) Compensation Scaling Factor and (d) Tool Mapping.

The Select Nodes function allows selection of local or global zones in the sprung parts for springback compensation calculation. The Undercut Option enables automatically backdraft detection and avoidance. An example of implementation of Undercut Option in springback compensation is illustrated in Figure 3. As shown in Figure 3a, the undercut (boxed regions) takes place without implementation of Undercut Option during springback compensation process. On the other hand, the undercut is check and avoided during the springback compensation process if the Undercut Option is turned on.

FIGURE 2. The springback compensation GUI packaged in DFE.
The Compensation Scaling Factor is the controlling variables that determine the amount of springback compensation in X, Y, Z or ALL directions during the springback compensation process. The controlling variables include displacement, displacement vector, stress and strain. Depending on the direction of springback, the Compensation Scaling Factor can be defined as either positive or negative values.

Upon the completion of springback compensation, the tooling mesh will be projected onto the compensated part mesh using the Tool Mapping function. After the tool mesh is mapped onto the compensated part mesh, the Tool Repair function can be utilized to manually or semi-automatically repair or smooth the compensated tool mesh. The compensated tool mesh is then used to conduct further formability and springback analysis. If the compensated tool mesh produces springback that is within the design tolerance, the original CAD surfaces will be mapped onto the compensated tool mesh using Surface Mapping function provided in DFE module. Otherwise, the die face compensation process is repeated following by another formability and springback analysis.

Through the iterative FEA simulations and die face compensation processes, one can obtain a die face that generates quality stamped part. Finally, automatic surface mapping, projection and manual morphing are carried out simultaneously to generate the NC quality CAD surfaces of the compensated or morphed die face. The flow chart of DFE based springback compensation process is shown in Figure 4.
FIGURE 4. A flow chart showing Die Face Engineering based springback compensation strategy.
IMPLEMENTATION OF DIE FACE ENGINEERING BASED SPRINGBACK COMPENSATION

Two benchmark examples are conducted to demonstrate the implementation of DFE based springback compensation strategy. The results of these benchmarks are briefly discussed.

**Simple U-Channel**
A simple U-Channel forming simulation is set up using eta/DYNAFORM Quick Setup module. The blank geometry is 1.0 mm x 30.0 mm x 175.0 mm. Due to symmetry, only half blank geometry is modeled. The blank material is HSLA250. A 25kN binder force is applied.

As indicated in Figure 5, the formed strip sprung backward by approximately 9° after springback analysis. The DFE based springback compensation processes are carried out to alleviate the springback. After the 1st compensation, it is discovered that the large compensation scaling factor has resulted in spring forward of the formed strip. The value of compensation scaling factor is then reduced in the 2nd compensation and the springback is gradually reduced with the dimension of the sprung strip close to the original formed strip.

![Figure 5](image1.png)
*FIGURE 5. Implementation of DFE based springback compensation on simple U-Channel.*

![Figure 6](image2.png)
*FIGURE 6. Implementation of DFE based springback compensation on Structural Rail.*
Automotive Structural Rail

The forming simulation and springback analysis are conducted for structural rail using DP600. After the springback analysis, severe springback is found on one end of the formed structural rail (shown in Figure 6). Therefore, the DFE based springback compensation is carried out to further demonstrate its capabilities to reduce springback severity. The springback analysis reveals the reduction of springback at section A-A after one iteration of springback compensation is performed.

CONCLUSION

The springback or shape change has been the greatest changes in the stamping industries. It has resulted in poor part quality and dimension, as well as the increase in lead time and the associated cost. This paper proposed a DFE based springback compensation strategy which uses an undercut detection and avoidance as the primary criteria during springback compensation processes. The springback compensation scheme combines both CAD and CAE methodology. The implementation of such strategy is demonstrated using simple U-Channel and automotive structural rail. The springback results are encouraging after the implementation of the springback compensation processing.

REFERENCE


**Correspondence:**

Chin Chun Chen  
Engineering Technology Associates, Inc.  
1133 E Maple Rd. Suite 200  
Troy, MI 48083  
U.S.A

Tel : +1-248-729-3010  
Fax : +1-248-729-3020  
e-mail : ccchen@eta.com